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COMPARATIVE ANALYSIS OF THE EFFECT OF GRAVITATIONAL STRESS
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It is sufficiently known from literature, that g-forces cause marked shifts in the functional state of the central nervous system, usually associated with the phenomena of acute hypoxia caused by disorders of cerebral circulation. Here, the authors came to the opinion, that hypoxia is one of the factors in the pathogenesis of disorders caused by accelerations. For experimental purposes, rabbits and cats were exposed to various gravitational stresses and the pO_2 was measured. The results are given.

A number of authors (Bibl.1 - 3, 11) have established that g-forces cause marked shifts in the functional state of the central nervous system which most researchers associate with the phenomena of acute hypoxia caused by disorders of cerebral circulation (Bibl.10, 17, 20, 25).

This point of view contradicts not only experimental data on the peculiarities of the occurrence of cerebral hypoxia (Bibl.7, 9, 15, 24, 25) and the possibilities of retaining constant cerebral circulation upon pronounced hemodynamic disturbances (Bibl.2, 8, 23), but also the results of direct investigations of cerebral circulation during the effect of g-forces (Bibl.13, 14, 19-22). Determinations of the oxygen content in the brain tissues by the polaro-

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** Numbers in the margin indicate pagination in the original foreign text.

graphic method (Bibl.12, 16) would help to answer this question, however such investigations are sporadic. It has been established in experiments on narcotized cats, that at average g-forces (precisely what, the author does not indicate) in a head-pelvis direction, pO_2 in the surface layers of the brain appreciably decreases (Bibl.18). Somewhat different results are obtained by other researchers (Bibl.4 - 6). It was demonstrated in chronic experiments on dogs, that a decrease in the pO_2 in brain tissues occurs only at forces greater than 4 g. At lower values of stress, the pO_2 in brain tissues even somewhat increases. As a result of investigations that have been carried out, the authors have concluded that hypoxia is "one of the basic factors in the pathogenesis of disorders caused by accelerations".

The present investigation is devoted to refining the problem of the specific significance of hypoxia in the mechanism of central-nervous system disorders under gravitational stresses and to elicit the effect of repeated g-forces on the pO_2 in brain tissues.

Method

Chronic experiments were staged on cats and rabbits. The oxygen tension in the brain tissues was determined polarographically (Bibl.12, 16) at a potential difference of 0.65 v. As the cathode, we used stationary platinum electrodes 0.14 mm in diameter, which were implanted by means of a stereotaxic apparatus into various divisions of the brain 5 - 7 days before starting the experiment. The anode was a 4-cm² silver chloride electrode, clamped to the inside surface of the ear. Diffusion currents were recorded by a VD-I micrograph produced by the Kipp Company (Holland).

Accelerations were produced by a centrifuge with a radius of 2 m. In

the experiments on cats we investigated the effect of accelerations from 2 to 23 g (head-pelvis direction) and from 2 to 10 g (pelvis-head direction). In the experiments on the rabbits, the magnitude of the g-forces was varied, respectively, from 2 to 12 and from 2 to 5 g. The duration of the forces was 1/20 1 to 1.5 min. To eliminate local stresses, the animals were placed in special containers, the shape of which conformed to their body. The inside walls of the container were lined with a layer of foam plastic.

The degree of hypoxia was estimated on the basis of altitude samples, i.e., the animals were "raised" in a pressure chamber to a "height" of 6000 and 10,000 m (cats) and 5000 and 8000 m (rabbits).

The "rise" and "descent" were accomplished at an average speed of 50 m/sec. The time that the animals stayed at the "height" of 5 and 6 km was 1.5 to 3 min and at a "height" of 8 and 10 km, less than 1 min. To eliminate the effect of one factor on the other, the "rise" to the "height" in some experiments was accomplished before, and in others, after the effect of the g-forces.

Respiration, EKG, and in some experiments the EEG, were recorded to judge the degree of tolerance to gravitational stresses. A total of 37 experiments were set up on four cats and eleven rabbits. In each experiment the animals were subjected 3 - 10 times to the effect of the stresses.

Results

No fundamental differences were noted in the pattern of the changes in pO_2 in the brain tissues of cats and rabbits under the effect of gravitational stresses. At the same time it was established that for rabbits the shifts of pO_2 occur at somewhat lower g-forces than for cats. No substantial differences were noted in the changes of pO_2 in the brain tissues of cats and rabbits when

they were "elevated".

Thus, the oxygen tension in brain tissues changed differently depending upon the magnitude, direction, and the currents of the effect of the g-forces, and the experimental data were analyzed from the point of view of the effect of each of these indices.

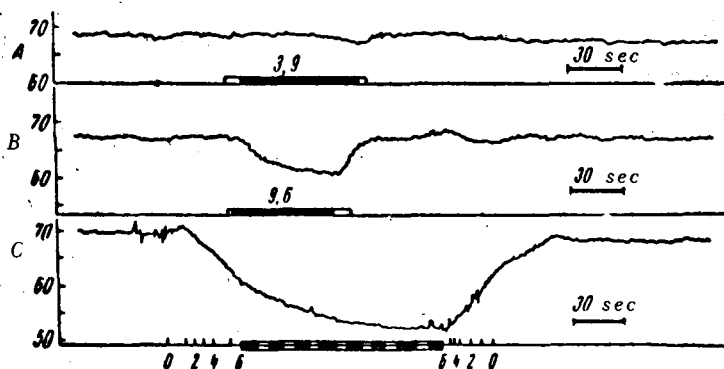


Fig.1 Effect of the Magnitude of g-Forces on the pO₂ in the Brain Tissues of a Cat.

A - Change of the pO₂ in the region of the superior colliculi of the corpora quadrigemina at a stress of 3.9 g in the head-pelvis direction; B - At a stress of 9.6 g; C - Upon "elevation" to 6000 m. Here and in Figs.2 and 3, the pO₂ is plotted on the y-axis in relative units; the time of the effect is plotted on the x-axis. The heavy line denotes the "platform" period of the g-force, the numeral above it indicates the magnitude of the latter; in the experiments with "elevation" of the animals, the "height" is plotted on the x-axis in kilometers.

At gravitational stresses in the head-pelvis direction from 1.5 to 3.5 g, the pO₂ in the brain tissues usually somewhat increased at the start of the stress or remained at the initial level (Fig.1).

At larger stresses, from 5 to 7 g (cats) and from 4.5 to 5.5 g (rabbits), the pO₂ in the brain tissues at first also somewhat increased at the start of the effect, but later, after 15 - 30 sec, it dropped either to the initial value or became even somewhat lower than it, remaining, however, within limits of the

physiological norm.

Gravitational stresses from 8 to 12 g (cats) and from 6 to 9 g (rabbits) led to a noticeable drop of the pO_2 in brain tissues, both in the cortex and in the subcortical structures. The drop was greater, the greater the magnitude and duration of the effect of acceleration. At the same time, it was not /21 possible to establish any rigorous dependence between the magnitude of the g-force and the pO_2 in the brain tissues.

TABLE
COMPARATIVE ESTIMATE OF THE CHANGES OF THE pO_2 IN BRAIN
TISSUES UNDER THE EFFECT OF g-FORCES AND IN THE
PRESENCE OF ACUTE HYPOXIA*

Effects	Number of Animals	Number of Determina- tions	M	σ	P	P (in Comparison with "Rise" to "Height")		
			In Comparison with the Initial State (in %)			5000 m	8000 m	10,000 m
Stresses in head- pelvis direction	11	26	95±1.6	8.1	<0.01	<0.01		
1.5 - 5.5 g	11	14	79±4.7	13.4	<0.01	=0.8	<0.01	
6.0 - 10 g	8	8	56±2.8	7.9	<0.01	<0.01	0.8	<0.01
14 - 18 g								
Stresses in pelvis- head direction,								
3 - 5 g	7	9	53±1.4	5.2	0.01	<0.01	0.9	<0.1
With "elevation" to "height" (in m)								
5000	11	17	78±0.3	5.8	<0.01			
8000	11	12	57±2.1	7.3	<0.01			
10,000	8	8	45±1.0	3.0	<0.01			

* The pO_2 value in the initial state was taken as 100.

The altitude tests showed, that during the effect of gravitational stresses the pO_2 in the brain tissue of the animal remained higher than when the animal was "raised" to a height of 5000 m. A more pronounced drop of the pO_2 (corre-

sponding to elevation to a height of 8000 - 10,000 m) was observed only when the cats were subjected to forces from 16 to 23 g and the rabbits to 14 - 18 g (see Table). At such gravitational stresses, pronounced disorders in the cardiac activity and in the external respiration occurred in the animals.

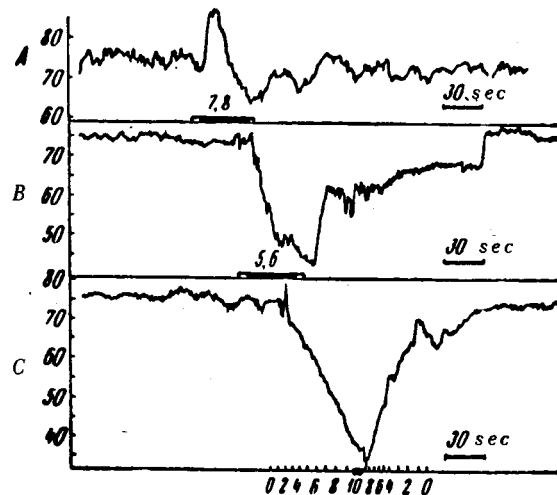


Fig.2 Effect of the Direction of g-Forces on the pO₂ Change in Brain Tissues of the Rabbit.

A - Change of the pO₂ in the region of the reticular formation of the tegmentum at a stress of 7.8 g in the head-pelvis direction; B - At a stress of 5.6 g in the pelvis-head direction; C - Upon "elevation" to a "height" of 10,000 m.

A completely different character of the changes of the pO₂ in brain tissues was noted when the g-forces were in a pelvis-head direction (see Fig.2 and Table). Even comparatively small g-forces caused a quite pronounced drop of the pO₂. Unlike gravitational stresses in the head-pelvis direction, with forces acting in the pelvis-head direction, the curve of the change of the pO₂ dropped almost vertically. A comparison with the data of the altitude tests showed that the pO₂ in the brain tissue dropped in this case to a level corresponding to a stay at an altitude of 8000 - 10,000 m. Substantial differences in the pO₂ changes under the effect of forces in the pelvis-head direction were

observed also in the immediate aftereffect period. Whereas with g-forces acting in the head-pelvis direction (average values), the restoration of pO_2 in the brain tissues began immediately after the effect ended and had a smooth character. This occurred differently when the forces acted in the pelvis-head direction.

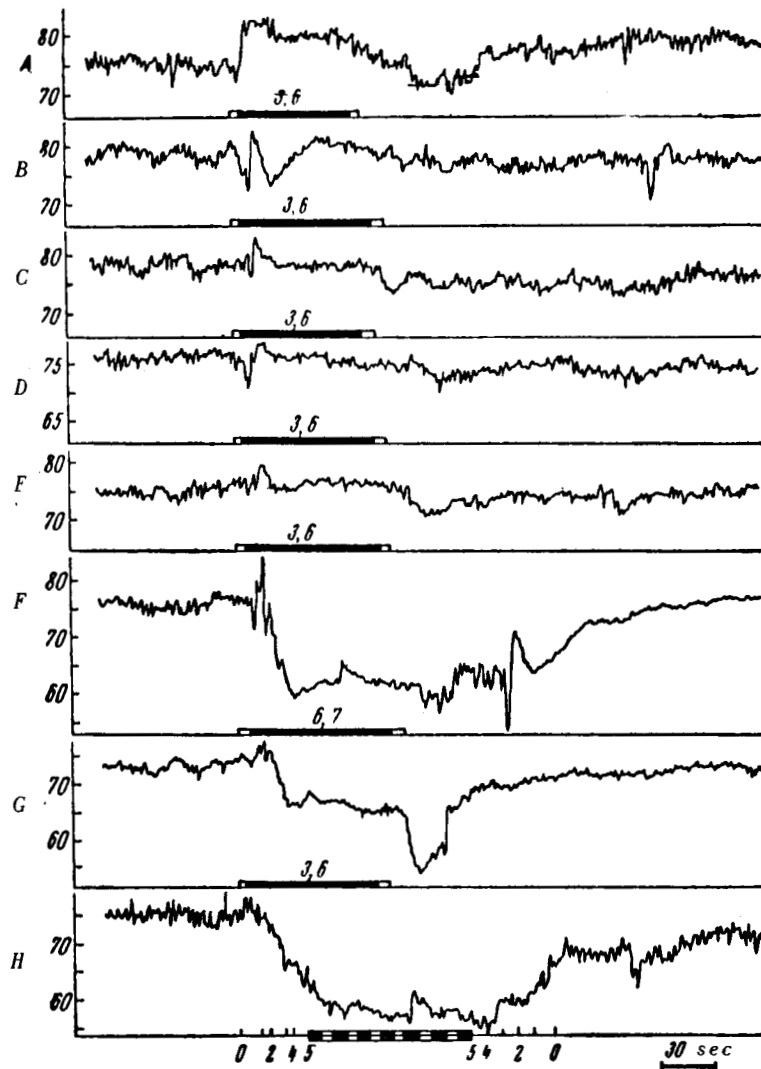


Fig.3 Effect of Repeated Exposures to g-Forces on the pO_2 in Brain Tissues of the Rabbits.
 A - E, G - Change of pO_2 in the region of the geniculate bodies at stresses of 3.6 g in a head-pelvis direction;
 F - At 6.7 g; H - Upon "elevation" to a "height" of 5000 m.

Depending on the magnitude of the stress, we noted two variants of the restoration of the original level of pO_2 ; in some cases it occurred extremely

slowly and stepwise, and in other cases it ensued only after a phase of an appreciable increase of oxygen tension. External respiration and the activity of the cardiovascular system (based on the EKG data) did not substantially change during the entire indicated period. The animal itself whose central nervous system, after the effect of the g-forces, was in a state of marked inhibition, immediately after the end of the phase of a high pO_2 began to respond to stimuli (pricking, puffing, etc.). Thus, the restoration of the activity of the animal occurred simultaneously with a decrease of the pO_2 in the brain /23 tissue. The first variant of restoration was observed in the case of the effect of small g-forces and the second at the maximally tolerable forces or after the repeated effect of the forces.

Experiments with the repeated effect of the gravitational stresses enabled us to establish that the pO_2 in brain tissues does not remain at the same level even if the magnitude of the g-forces does not change. The changes of the pO_2 were especially pronounced when the forces approached the maximally tolerable. Figure 3 shows the data of one of the experiments in which the animal was subjected 7 times to the effect of g-forces in 45 min. The value of all forces, except the 6th, was 3.6 g. As we see from Fig.3, the pO_2 in the brain tissue changed with each subsequent effect somewhat differently than with the preceding one. The most expressed shifts of pO_2 were observed after the 6th gravitational stress, which caused a unique "detachment" of the compensation mechanisms. As a result of this, during the 7th exposure to g-forces (also 3.6 g), the pO_2 in the brain tissue dropped almost to the same level as during the effect of the 6th exposure. However, we see from the comparison with the result of the altitude test that in this case the pO_2 in the brain tissues remained at a higher level than with "rise" to a "height" of 5000 m.

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